

## Section 6 Analysis of Nonmarine Mollusks

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### 6.1 Introduction

Dr. Carl C. Christensen's study *Analysis of Nonmarine Mollusks from Selected Sites in the City Center (Construction Section 4) of the Honolulu High-Capacity Transit Corridor Project, Kalihi, Kapālama, Honolulu, and Waikīkī Ahupua'a, Honolulu (Kona) District, Island of O'ahu, TMK [1] 1-2, 1-5, 1-7, 2-1, 2-3 (Various Plats and Parcels)* addressing a total of 11 samples (with a total of 12 taxa indicated) from eight separate Test Excavations, follows this introduction in full. The reader is directed to this study for details. A brief synopsis prepared for the layperson is given below and in Table 260.

### 6.2 Summary of the Archaeological Import of the Snail Study

#### 6.2.1 Overview of the Archaeological Import of the Snails

The Christensen (2013) study identified twelve species of nonmarine mollusks. These mollusks are briefly described in this section in terms of their import for this archaeological study.

##### Three Semi-Amphibious Species (Figure 59 to Figure 61)

- *Assiminea parvula*,
- *Blauneria gracilis*, and
- *Melampus* sp.

##### Six Aquatic Species Inhabiting Fresh- or Brackish-Water Environments (Figure 62 to Figure 67)

- *Tryonia porrecta* (native to Hawai'i),
- *Melanoides tuberculata* (Polynesian introduction),
- *Tarebia granifera* (Polynesian introduction),
- *Lymnaea viridis* (established in Hawai'i post-1778),
- *Physa* cf. *acuta* (established in Hawai'i post-1778), and
- *Planorbella duryi* (established in Hawai'i post-1778)

##### Three Truly Terrestrial Species (Figure 68 to Figure 70)

- “*Succinea*” sp. (native to Hawai'i),
- *Hawaiiia minuscula* (established in Hawai'i post-1778), and
- *Bradybaena similaris* (established in Hawai'i post-1778)

All 8 Test Excavation locations sampled, and all 11 samples, have aquatic snails indicating a fresh- or brackish-water environment was present in all cases. The species *M. tuberculata* requires permanent water. The presence of this species in all samples except at T-131 indicates permanent water in all of the other locations sampled.

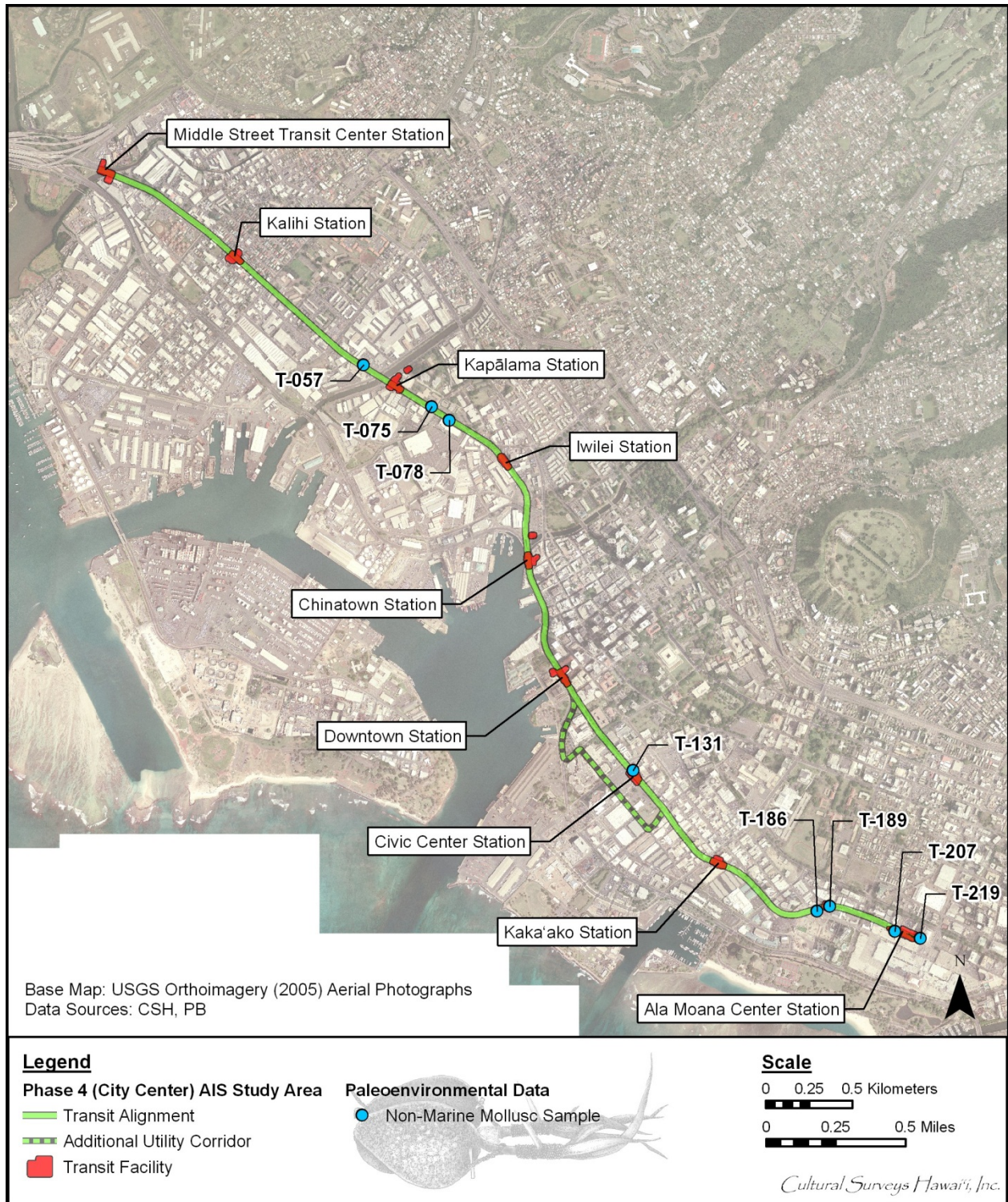


Figure 58. Locations of the 8 Test Excavations for which analysis of nonmarine mollusks is reported



Figure 59. *Assiminea parvula*, semi-amphibious mollusk (Photo credit: McCormack, G. 2007)



Figure 60. *Blauneria gracilis*, semi-amphibious mollusk (Photo credit: Pittman, Cory 1988)



Figure 61. *Melampus*, semi-amphibious mollusk (Photo credit: Pittman, Cory 2009)

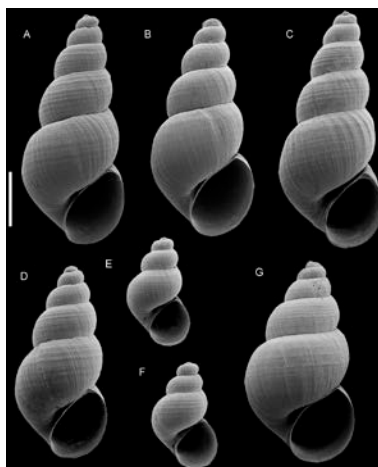


Figure 62. *Tryonia porrecta*, fresh- brackish-water species (Photo credit: Hershler, Robert et al. 2007)



Figure 63. *Melanoides tuberculata*, fresh- brackish-water species (Photo credit: Poppe, G. and P. Poppe 2013)



Figure 64. *Tarebia granifera*, fresh- brackish-water species (Photo credit: Poppe, G. and P. Poppe 2013)



Figure 65. An example of a gastropod from the Lymnaea family (photo of *Lymnaea viridis* not available (Photo credit: Poppe, G. and P. Poppe 2013)



Figure 66. *Physa acuta*, fresh- brackish-water species (Photo credit: Schutes, F.W., date unknown)



Figure 67. *Planorbella duryi*, fresh- brackish-water species (Photo credit: Rittner,Oz, date unknown)



Figure 68. *Succinea caduca* (O'ahu Island), terrestrial mollusk (Photo credit: Poppe, G. and P. Poppe 2013)



Figure 69. *Hawaiiia minuscula*, terrestrial mollusk (Photo credit: Poppe, G. and P. Poppe 2013)



Figure 70. *Bradybaena similaris*, terrestrial mollusk (Photo credit: Poppe, G. and P. Poppe 2013)

### 6.2.2 Test Excavation Specific Conclusions

Insights into the environmental history and land-use are presented below for each Test Excavation unit.

#### T-057

The presence of an estuarine, strandline, and shoreline-dwelling species, *A. parvula*, is consistent with a coastal location. A fresh- or brackish-water environment was present with the presence of *M. tuberculata* indicating permanent water. The presence of a truly terrestrial mollusk, *H. minuscula*, suggests this specimen may have been washed in from adjacent dry land localities. The presence of historically introduced alien species, *L. viridis* and *H. minuscula*, indicates the sample dates to the historic period (or that it was subject to contamination from more recent sediments) and would be consistent with mid- to late-nineteenth century (or later) rice cultivation.

#### T-075

A fresh- or brackish-water environment was present with the presence of *M. tuberculata* indicating permanent water.

#### T-078

The presence of an estuarine, strandline, and shoreline-dwelling species, *A. parvula*, is consistent with a coastal location (Figure 71). A fresh- or brackish-water environment was present with the presence of *M. tuberculata* indicating permanent water. The presence of a truly terrestrial mollusk, *B. similis*, suggests this specimen may have been washed in from adjacent dry land localities. The presence of a historically introduced alien species, *L. viridis*, indicates the sample dates to the historic period (or that it was subject to contamination from more recent sediments) and would be consistent with mid- to late-nineteenth century (or later) rice cultivation.

#### T-131

The presence of an estuarine, strandline, and shoreline-dwelling species, *A. parvula*, is consistent with a coastal location. A fresh- or brackish-water environment was present. The absence of *M. tuberculata* may indicate the water was not “permanent.” Christensen, in his 2013 report on the subject included as section 1.3 notes that the abundant presence of a native snail, *T. porrecta*, and the absence of two Polynesian introduced species, *M. tuberculata* and *T. granifera*, suggests this sample may pre-date human settlement.

#### T-186 (two samples)

The presence of estuarine, strandline, and shoreline-dwelling species, *A. parvula* and *Melampus* sp., is consistent with a coastal location. A fresh- or brackish-water environment was present with the presence of *M. tuberculata* indicating permanent water. There were no significant differences between the two samples. There was no evidence indicative of change over time.

**T-189 (two samples)**

The presence of estuarine, strandline, and shoreline-dwelling species, *A. parvula* and *Melampus* sp., is consistent with a coastal location (Figure 72). A fresh- or brackish-water environment was present with the presence of *M. tuberculata* indicating permanent water. The presence of a truly terrestrial mollusk, “*Succinea*,” suggests this specimen may have been washed in from adjacent dry land localities. There were no significant differences between the two samples. There was no evidence indicative of change over time.

**T-207**

The presence of estuarine, strandline, and shoreline-dwelling species, *A. parvula* and *B. gracilis*, is consistent with a coastal location. A fresh- or brackish-water environment was present with the presence of *M. tuberculata* indicating permanent water.

**T-219 (two samples)**

The presence of an estuarine, strandline, and shoreline-dwelling species, *A. parvula*, is consistent with a coastal location (Figure 73 and Figure 74). A fresh- or brackish-water environment was present with the finding of *M. tuberculata* indicating permanent water. The presence of historically introduced alien species, *Physa* sp. and *P. duryi*, in the Stratum IIa sample (but not in the sample from Stratum IIb) indicates the IIa sample dates to the historic period (or that it was subject to contamination from more recent sediments) and would be consistent with mid- to late-nineteenth century (or later) rice cultivation as represented in the Stratum IIa sample.



Figure 71. Fresh- brackish-water gastropods (snails) within T-078, Stratum IIb



Figure 72. Fresh- brackish-water gastropods (snails) and organic matting within T-189, Stratum III



Figure 73. Fresh- brackish-water gastropods (snails) within T-219, Stratum IIa



Figure 74. Fresh- brackish-water gastropods (snails) within T-219, Stratum IIb

## 6.3 Nonmarine Mollusks Analysis by Carl C. Christensen, Ph.D.

**Analysis of Nonmarine Mollusks from Selected Sites in the City Center (Construction Section 4) of the Honolulu High-Capacity Transit Corridor Project, Kalihi, Kapālama, Honolulu, Waikīkī Ahupua‘a, Honolulu (Kona) District, Island of Oahu, TMK [1] 1-2, 1-5, 1-7, 2-1, 2-3 (Various Plats and Parcels)**

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### 1. Introduction

At the request of Cultural Surveys Hawai'i, Inc. ("CSH"), analysis was undertaken of nonmarine mollusks obtained during excavations at selected locations along the right-of-way of the proposed Honolulu High-Capacity Transit Corridor Project in the ahupua‘a of Kalihi, Kapālama, Honolulu, and Waikīkī in the Kona District of the Island of Oahu, City and County of Honolulu. The analysis was intended to identify the species of nonmarine mollusks formerly inhabiting the site and to determine what information, if any, the observed composition of the mollusk fauna could provide regarding former conditions at the sites studied.

Shells representing twelve species of nonmarine mollusks were obtained: three semi-amphibious species inhabiting shoreline/strandline habitats [*Assiminea parvula* (Mousson 1865), *Blauneria gracilis* (Pease 1860), and *Melampus* sp.], six aquatic species inhabiting fresh- or brackish water environments (*Tryonia porrecta* (Mighels 1845), *Melanoides tuberculata* (Müller 1774), *Tarebia granifera* (Lamarck 1816), *Lymnaea viridis* (Quoy & Gaimard 1832), *Physa* cf. *acuta* (Draparnaud 1804), and *Planorbella duryi* (Wetherby 1879), and three are truly terrestrial species ("Succinea" sp., *Hawaiiia minuscula* (Binney 1840), and *Bradybaena similis* (Rang 1831). Five of these (*L. viridis*, *P. sp. cf. acuta*, *P. duryi*, *H. minuscula*, and *B. similis*) are alien species that became established in the Hawaiian Islands after the initiation of European contact in AD 1778, and two (*M. tuberculata* and *T. granifera*) are believed to have been introduced to the Hawaiians by human commerce prior to AD 1778, although the possibility has not been ruled out that one or both of them may be native here. *T. porrecta* and probably also "Succinea" are native to Hawaii.

### 2. Materials and Methods

Excavations were carried out by CSH personnel along the proposed right-of-way of the Honolulu High-Capacity Transport Corridor Project in the ahupua‘a of Kalihi, Kapālama, Honolulu, and Waikīkī in the Honolulu (Kona) District of the Island of Oahu, the State of Hawai'i. A full archaeological report of the excavations (CSH 2013) can be found in the volume to which the present analysis is an appendix. At a selection of the sites where nonmarine mollusks were encountered, CSH personnel took bulk samples of sediment for snail analysis. Soil samples of known volume were wet-screened using a screen of 1/16 inch mesh size; the

residue was then air-dried, weighed, and submitted for snail analysis. The residue was examined under a low-power microscope and all countable nonmarine mollusk shells were removed. To avoid double-counting of broken shells, specimens are considered “countable,” and are this included in the quantitative results presented [at the end of this section] in Table 1, if they included a complete shell apex or, in those species where the apex is often lost to erosion (i.e., the shell is decollate), the broken apex had been replaced by a calcareous plug, indicating that the erosion had occurred pre-mortem and that the specimen being counted was not a mere basal fragment of an individual shell with a broken apex that would likely be counted separately, with attendant problems of double-counting. Data are presented as actual counts of specimens, with the exception that the number of specimens in lots containing in excess of 1000 specimens were estimated. In instances where a species was represented in a sample only by broken (i.e., non-apical fragments), their presence is indicated in Table 1 with a plus sign (+). Specimens were identified by reference to available literature and, where necessary, by comparison with identified material in the malacology collections of the Bishop Museum. All specimens will be deposited in that collection.

### 3. Systematic Review

#### **Family Cochliopidae (formerly Hydrobiidae, in part)**

##### ***Tryonia porrecta* (Mighels 1845)**

*Tryonia porrecta* is a freshwater snail that is apparently native to the Hawaiian Islands but is also found in North America in California and the Great Basin region. It has been found throughout the Hawaiian Islands and is often abundant in sediments from fishponds and taro fields of prehistoric and historic age, but has virtually disappeared from such sites since the early Twentieth Century (Christensen 2012 and references cited therein).

#### **Family Thiaridae**

##### ***Melanoides tuberculata* (Müller 1774)**

*Melanoides tuberculata* is a common inhabitant of fresh- and brackish-water habitats in the Hawaiian Islands. The species is known to be native to Africa and Indonesia but has spread throughout the tropics within the last several hundred years. It is probably a prehistoric introduction in Hawaii, but the possibility cannot yet be excluded that it is native here (Christensen 2012 and references cited therein).

##### ***Tarebia granifera* (Lamarck 1816)**

*Tarebia granifera* has much the same ecology and history as the last species, although its native range is believed to be limited to Indonesia and Southeast Asia; it, too, is a globally invasive species that was present in the Hawaiian Islands prehistorically but may be indigenous here (Christensen 2012 and references cited therein).

#### **Family Assimneidae**

##### ***Assiminea parvula* (Mousson 1865)**

This native species, long known as *Assiminea nitida* (Pease 1865), is widely distributed in the Pacific, occurring from the Philippines and Micronesia eastwards to Hawaii and French Polynesia; it is a semi-aquatic strandline species that can be found living under rubble at and near the shoreline (Abbott 1958; Kay 1979).

**Family Ellobiidae*****Blauneria gracilis* (Pease 1860)**

This species was described from Hawaiian material, but as Kay (1979) noted, as of the date of her writing it had not been recorded in Hawaii since its original description. Subsequently, however, two specimens have been obtained from archaeological sites on Molokai and Oahu (Cowie et al. 1995). Non-Hawaiian records are from Tahiti (Grasset 1884) and Mauritius (Nevill 1878; Griffith & Florens 2006), although their identity with the Hawaiian species is unconfirmed. *B. gracilis* was apparently at least moderately abundant in Hawaii at the time of its discovery, as Pease (1869:60) was able to describe its habitat with some specificity, stating that “Its station is similar to that of *Pedipes*, which is found in the crevices of stones overflowed at high water. I have never found *B. gracilis* on the sides or tops of stones when the tide was out, but around their base when the water stood in little pools.” Nevertheless, the species seems to have become extinct in Hawaii since that time.

***Melampus* sp.**

Several worn specimens of an unidentified species of *Melampus* were obtained. Two species, *M. castaneus* (Megerle von Mühlfeld 1816) and *M. parvulus* (Pfeiffer 1846), are reported to occur in the Hawaiian Islands; both occur along the shoreline in the supraspray zone among rocks and rubble (Kay 1979).

**Family Lymnaeidae*****Lymnaea viridis* (Quoy & Gaimard 1832)**

Cowie (1997) reported this species (as *Fossaria viridis*) to have been present in the Hawaiian Islands since 1890. It has also been reported as *Lymnaea ollula* and is the principal intermediate host in Hawaii of the liver fluke *Fasciola gigantica*, an economically significant parasite of cattle (Alicata 1937, 1938, 1964) that can also infect humans, occasionally with fatal results (Alicata 1953, Stemmermann 1953). Recent molecular phylogenetic studies (Remigio 2002; Puslednik et al. 2009; Correa et al. 2010) have confirmed the identity of Hawaiian populations of this species with *L. viridis*. In addition to the Hawaiian Islands, this Asian species had become established on Guam before 1832 (Cowie 1997) and now occurs Australia (Ponder & Waterhouse 1997; Puslednik et al. 2009).

**Family Physidae*****Physa* sp. cf. *acuta* (Draparnaud 1805)**

Cowie (1997:8–9) reports that three names have been applied to Hawaiian *Physa*: *P. compacta* (Pease 1870), *P. elliptica* (Lea 1834), and *P. virgata* (Gould 1855), but [he] comments that Hawaiian physids “are very poorly documented and their identifications are uncertain.” Two of these taxa, *P. elliptica* and *P. virgata*, are undoubtedly modern introductions of North American origin; Cowie reports that the third, *P. compacta*, may be a native sinistral lymnaeid, but also cites Johnson (1994) as stating that *compacta* is a synonym of *P. mexicana* (Philippi 1841), another North American species. Taylor (2003:8) identified Hawaiian physids as *Haitia mexicana* (Philippi 1841), which he stated was “now on all the larger Hawaiian Islands.” Burch (1982) and Taylor (2003) place *elliptica* in the synonymy of *Physella gyrina* (Say 1821), whereas Wethington & Dillon (2009) place *mexicana* and *virgata* in the synonymy of *Physa acuta* (Draparnaud 1805). Dillon et al. (2002:233) note that *P. acuta* has spread from its North American homeland to Europe, Africa, southern Asia, Australia, and Japan [also South America

and the Middle East (Madsen & Frandsen 1989; Albrecht et al. 2009) and “might reasonably be nominated as the world’s most cosmopolitan freshwater gastropod.” *P. gyrina* is a much less invasive species, but has become established in Great Britain and Ireland (Anderson 2003) and Spain (Cobo et al. 2010). In light of Taylor’s identification of Hawaiian physids as what is now known as *P. acuta* and that species’ strongly invasive tendencies, it is likely (though not yet certain) that Hawaiian physids (including the material; examined here) are *P. acuta*; whichever species they are, however, they are undoubtedly post-1778 introductions. Physids have been present in the Hawaiian Islands since at least 1905, when C. M. Cooke, Jr., collected specimens (BPBM 14776) at Kewalo, Oahu, very near the present study site.

### **Family Planorbidae**

#### ***Planorbella duryi* (Wetherby 1879)**

*Planorbella duryi* (Wetherby 1879), including subspecies *P. d. normale* (Pilsbry 1934), is native to Florida (Pilsbry 1934; Baker 1945) but has become widely distributed elsewhere as a result of human commerce; it occurs in Africa from Egypt to South Africa and also on the islands of Mauritius and Reunion in the Indian Ocean as well as Israel, Saudi Arabia, and South America (Madsen & Frandsen 1989; Brown 1994; Cowie 1997; Pointier et al. 2005); most recently, it has extended its range to Siberia (Sitnikova et al. 2010). It is a post-1778 introduction to the Hawaiian Islands, and although no published record of its occurrence here appeared until 1969 (Wallace & Rosen 1969; Cowie 1997), Bishop Museum’s collection documents its presence on the Island of Hawaii in 1913 (BPBM 33993), and the species probably became established here somewhat before that date.

### **Family Succineidae**

#### **“*Succinea*” sp.**

Numerous species of Succineidae are native to the Hawaiian Islands (Cowie et al. 1995), but species and even generic-level identification is often dependent upon anatomical characters not available in a subfossil shell. Accordingly, no precise identification is possible of the single broken succineid shell recovered during this study.

### **Family Pristilomatidae (formerly Zonitidae, in part)**

*Hawaia minuscula* (Binney 1840) is a land snail species native to North America, where it has a fossil record dating back to the lower Miocene (La Rocque 1970); fossil occurrences on islands adjacent to Japan (Chiba et al. 2008) indicate that it may be native there as well. The species occurs from Alaska to South America (Pilsbry 1946; La Rocque 1970), though it is uncertain whether its presence in South America is natural or the result of human commerce (Hausdorf 2002). Elsewhere, it has become established as an alien on Pitcairn Island and Tahiti in Polynesia and in Europe, Africa, Asia, New Caledonia, and Australia (Baker 1940; Pilsbry 1946; Solem 1964; Smith 1989, 1992). It had become established in the Hawaiian Islands by the 1850s (Baker 1940; Solem 1964; Cowie 1997).

*H. minuscula* has been reported to occur in “wet locations such as floodplains of creeks and rivers” and also in woodlands, among grasses, and in disturbed areas (La Rocque 1970:639).

### **Family Bradybaenidae**

#### ***Bradybaena similis* (Rang 1831)**

*Bradybaena similis* is a terrestrial snail probably native to Asia and Indonesia but now widely dispersed throughout the Pacific by modern commerce. The earliest Hawaiian record is from 1893 (Cowie 1997; Brook 2010). In Hawaii, it is a common garden snail but also occurs in both wet and dry forested areas not associated with human habitation sites.

#### **4. Site Reports**

The following brief site descriptions were provided by CSH personnel; more complete accounts may be found elsewhere in this study (Cultural Surveys Hawaii, Inc, 2013).

##### **T-057**

Trench T-057 is located on “Dillingham Blvd, just west of Kapālama Stream.” Sediment description (Stratum II): “Bluish-black silty clay; natural wetland sediment; likely former taro lo‘i and rice paddies; stratum contains burnt wood log.”

A bulk sample of 0.25 liters of sediment was taken from Stratum II at a depth of 162 cm b.s. on September 18, 2012. After screening, a residue of 13.7 g remained for analysis.

##### **T-075**

Trench T-075 is located on “Dillingham Blvd, east of Kapālama Stream.” Sediment description (Stratum IIb): “Very dark gray silty clay; organic wetland sediment with preserved plant material; formerly area of taro lo‘i and rice paddies; underlying a layer of silty clay (IIa); stratum contains charcoal.”

A bulk sample of 3.0 liters of sediment was taken from Stratum IIb at a depth of 168–195 cm b.s. on May 14, 2012. After screening, a residue of 13.9 g remained for analysis.

##### **T-078**

Trench T-078 is located on “Dillingham Blvd, east of Kapālama Stream. Sediment description (Stratum IIb): “Dark gray silty clay; organic wetland sediment with matted grass material; formerly area of taro lo‘i and rice paddies; stratum contains charcoal.”

A bulk sample of 3.0 liters of sediment was taken from Stratum IIb at a depth of 180–190 cm b.s. on September 18, 2012. After screening, a residue of 12.9 g remained for analysis.

##### **T-131**

Trench T-131 is located on “Halekauwila Street between Cooke and South Streets.” Sediment description (Stratum II): “Dark gray silty sandy clay; stratum overlies coral shelf.”

A bulk sample of 2.0 liters of sediment was taken from Stratum II at a depth of 133 cm b.s. on October 24, 2012. After screening, a residue of 12.3 g remained for analysis.

##### **T-186 (2 samples)**

Trench T-186 is located on Queen Street “just outside the recorded boundaries of [Kolowalu Fishpond], and therefore should be categorized as natural, non-man modified wetlands.” Sediment description (Stratum IIa/IIb): “Black clay loam/ gray sandy clay loam; IIa is an old A-horizon with decaying organic matter (with very fine micro-layers of peat); IIb is natural lagoonal sediment”; (Stratum III): “Light greenish gray loamy sand; located above coral shelf.”

A bulk sample of 2.5 liters was taken from Stratum IIa/IIb at a depth of 124–137 cm b.s. on September 20, 2012. After screening, a residue of 25.3 g remained for analysis. A second bulk

sample of 3.0 liters of sediment was taken from Stratum III at a depth of 135–145 cm b.s. on the same date. After screening, a residue of 27.3 g remained for analysis.

#### **T-189 (2 samples)**

Trench T-189 is “located along Kona Street [in the vicinity of the Ala Moana Shopping Center] in the former Kewalo/Kalia natural wetlands” and is “located just outside the boundaries of the Kolowalu Fishpond.” Sediment description (Stratum II): “Very dark gray fibrous loam; old A-horizon”; (Stratum IIIa): Dark grayish brown silty clay loam; stratum contains charcoal.”

A bulk sample of 2.0 liters of sediment was taken from Stratum II at a depth of 138–142 cm b.s. on December 15, 2012. After screening, a residue of 6.2 g remained for analysis. A second bulk sample of 3.0 liters of sediment was taken from Stratum IIIa at a depth of 155–165 cm b.s. on the same date. After screening, a residue of 13.2 g remained for analysis.

#### **T-207**

Trench T-207 is “located along Kona Street [in the vicinity of the Ala Moana Shopping Center] in the former Kewalo/Kalia natural wetlands.” Sediment description (Stratum IIb): “Dark gray clay; wetland sediment; pollen analysis of the overlying sandy clay sediment (IIa) indicates that IIa was a very wet environment that gradually became less wet over time (upper IIa).”

A bulk sample of 1.0 liter of sediment was taken from Stratum IIb at a depth of 135–170 cm b.s. on October 15, 2012. After screening, a residue of 12.3 g remained for analysis.

#### **T-219 (2 samples)**

Trench T-219 is “located along Kona Street [in the vicinity of the Ala Moana Shopping Center] in the former Kewalo/Kalia natural wetlands.” Sediment description (Stratum IIa): “Black silty clay; organic marsh sediment with peat; stratum contains charcoal”; (Stratum IIb): “Gray sandy clay; pond sediment; stratum contains charcoal.”

A bulk sample of 1.0 liter of sediment was taken from Stratum IIa at a depth of 110–175 cm b.s. on October 14, 2012. After screening, a residue of 5.6 g remained for analysis. A second bulk sample of 3.0 liters of sediment was taken from Stratum IIb at a depth of 140–175 cm b.s. on the same date. After screening, a residue of 15.2 g remained.

### **5. Discussion**

Aquatic snails characteristic of fresh- or brackish-water environments predominate in all of the samples analyzed, constituting more than 80% of the total shells present in the samples taken at T-189 (Stratum II) and T-207 and more than 95% of the shells present in all other samples. The only other species present in any real abundance is a strandline/shoreline species, *Assiminea parvula*, which reached its maximum abundance (17.2% of all shells present) at T-207, but was present in smaller numbers at all sites studied except T-075; no other species attained a relative abundance in excess of 1.2% in any sample.

Although little is known of the ecologically limiting parameters of most of the nonmarine mollusks represented in these samples, it is known that *M. tuberculata*, though tolerant of pollutants and able to inhabit sites with a broad range of salinity, requires permanent water and is absent from waterways that regularly dry out (Brown 1980). Accordingly, its presence in all sites except T-131 indicates that these sites had permanent water.

The sample from T-075, a site formerly cultivated in taro and later rice, is unusual both in the absence of *T. porrecta*, one of the most abundant species in all other samples, and in the heavily eroded nature of the shells of the two thiarid species present (this erosion could be indicative of a low pH environment or one low in the calcium carbonate snails need to construct their shells).

The absence of the two thiarid species *M. tuberculata* and *T. granifera* at T-131 is difficult to explain; the abundant presence there of *T. porrecta* indicates that the site was a wetland, and as both thiarids are ecologically tolerant it is unlikely that conditions suitable for *Tryonia* would be inhospitable to *Melanoides* and *Tarebia*. One possible (though highly speculative) explanation is that this stratum may antedate human settlement in the Hawaiian Islands. If *Tryonia* is indeed native to the Hawaiian Islands and if the two thiarids are prehistoric introductions, as is believed to be true (Christensen 2012), then the unusual composition of the T-131 sample would be consistent with an age earlier than human settlement and the prehistoric introduction of the thiarids.

Historically introduced alien species (*Lymnaea viridis*, *Physa* sp., *Planorbella duryi*, *Hawaiiia minuscula*, and *Bradybaena similaris*) are present in samples from T-057, T-078, and T-219 (Stratum IIa), indicating that the sediments sampled either date to the historic period (probably mid- to late-nineteenth century or later) or are subject to contamination from more recent sediments. The presence of these modern aliens is consistent with the conclusion that T-057 and T-075 were formerly cultivated in rice, a crop unknown to the pre-Contact Hawaiians. As these recent aliens are never abundant in those samples in which they are present, however, their absence from another site believed to be associated with rice cultivation (T-075) is not necessarily significant (it should be noted that the T-075 sample is *also* unusual in the absence of *T. porrecta* and the strongly eroded nature of most of the thiarid shells obtained).

The presence in most samples (all except T-075) of estuarine, strandline, and shoreline-dwelling species (*Assiminea parvula*, *Blauneria gracilis*, and *Melampus* sp.) is consistent with the coastal location of these sites

Finally, a very small number of shells of truly terrestrial mollusks ("*Succinea*," *Hawaiiia minuscula*, and *Bradybaena similaris*) were present in a few sites (T-057, T-078, and T-189 Stratum III); these specimens may have been washed in from adjacent upland localities, perhaps located in close proximity to the coastal wetlands that were the home of the aquatic species represented.

## 6. Conclusion

The abundance of aquatic snails at these sites confirms other evidence that most, if not all, of these sites were once permanent wetlands. The presence of alien species believed to have been introduced either prehistorically or during the modern era can supplement chronological information from radiocarbon analysis and other sources.

## 7. Literature Cited

[Note: Not all sources used for Dr. Christensen's analysis are actually listed here in the "Literature Cited" section. Please also note: Dr. Christensen formatted this section with only first (and sometimes middle) initials and full last names.]

### **Abbott, R. T.**

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Table 260. Quantitative results of snail analysis from selected sites along the proposed right-of-way of the Honolulu High-Capacity Transit Corridor, Kalihi, Kapālama, Honolulu, and Waikīkī Ahupua'a, Honolulu (Kona) District, Island of Oahu, TMK [1] 12, 1-5, 1-7, 2-1, 2-3 (Various Plats and Parcels).

Provenience	T-057	T-075	T-078	T-131
Depth	162 cmbs	168–195 cmbs	180–190 cmbs	133 cmbs
Stratum	II	IIb	IIb	II
Vol./Weight	0.25 l/13.7 g	3.0 l/13.9 g	3.0 l/12.9 g	2.0 l/12.3 g
Taxon				
<i>Tryonia porrecta</i>	32 (12.2%)	-	704 (83.8%)	2500* (100.0%)
<i>Melanoides tuberculata</i>	36 (13.7%)	13 (22.4%)	29 (3.4%)	-
<i>Tarebia granifera</i>	188 (71.5%)	45 (77.6%)	96 (11.4%)	-
<i>Assiminea parvula</i>	1 (0.4%)	-	1 (0.1%)	1 (0.0%)
<i>Blauneria gracilis</i>	-	-	-	-
<i>Melampus</i> sp.	-	-	-	-
<i>Lymnaea viridis</i>	5 (1.0%)	-	10 (1.2%)	-
<i>Physa</i> sp. cf. <i>acuta</i>	-	-	-	-
<i>Planorbella duryi</i>	-	-	-	-
“ <i>Succinea</i> ” sp.	-	-	-	-
<i>Hawaiiia minuscula</i>	1 (0.4%)	-	-	-
<i>Bradybaena similaris</i>	-	-	+ (+)	-
Total	263 (100%)	58 (100%)	840 (100%)	2501 (100%)

\*estimated

Provenience	T-186	T-186	T-189	T-189
Depth	124–137 cmbs	135–145 cmbs	138–142 cmbs	155–165 cmbs
Stratum	IIa/IIb	III	II	III
Vol./Weight	2.5 l/25.3 g	3.0 l/ 27.3 g	2.0 l/6.2 g	3.0 l/13.2 g
Taxon				
<i>Tryonia porrecta</i>	523 (78.0%)	24 (66.7%)	110 (61.8%)	1500* (94.2%)
<i>Melanoides tuberculata</i>	131 (19.7%)	11 (30.7%)	28 (15.7%)	37 (2.3%)
<i>Tarebia granifera</i>	7 (1%)	-	5 (2.8%)	5 (0.3%)
<i>Assiminea parvula</i>	2 (0.3 %)	1 (2.8%)	33 (18.5%)	48 (3.0%)
<i>Blauneria gracilis</i>	-	-	-	-
<i>Melampus</i> sp.	1 (0.2 %)	-	2 (1.1%)	2 (0.1 %)
<i>Lymnaea viridis</i>	-	-	-	-
<i>Physa</i> sp. cf. <i>acuta</i>	-	-	-	-
<i>Planorbella duryi</i>	-	-	-	-
“ <i>Succinea</i> ” sp.	-	-	-	1 (0.0%)
<i>Hawaiiia minuscula</i>	-	-	-	-
<i>Bradybaena similaris</i>	-	-	-	-
Total	664 (100%)	36 (100.0%)	178 (100.0%)	1593 (100.0%)

\*estimated

Provenience	T-207	T-219	T-219
Depth	135–170 cmbs	110–175 cmbs	140–175 cmbs
Stratum	IIb	IIa	IIb
Vol./Weight	1.0 l/12.3 g	1.0 l/5.6 g	3.0 l/15.2 g
Taxon			
<i>Tryonia porrecta</i>	143 (48.2%)	127 (47.6%)	1500* (88.0%)
<i>Melanoides tuberculata</i>	72 (24.25%)	101 (37.8%)	116 (6.8%)
<i>Tarebia granifera</i>	24 (8.1%)	30 (11.2%)	59 (3.5%)
<i>Assiminea parvula</i>	51 (17.2%)	6 (2.2%)	30 (1.7%)
<i>Blauneria gracilis</i>	3 (1.0%)	-	-
<i>Melampus</i> sp.	-	-	-
<i>Lymnaea viridis</i>	-	-	-
<i>Physa</i> sp. cf. <i>acuta</i>	-	2 (0.8%)	-
<i>Planorbella duryi</i>	-	1 (0.4%)	-
“ <i>Succinea</i> ” sp.	-	-	-
<i>Hawaiiia minuscula</i>	-	-	-
<i>Bradybaena similis</i>	-	-	-
Total	293 (100%)	267 (100%)	1705 (100%)

\*estimated